Ground/Water Treatment & Technology, LLC

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Date: December 18, 2015

Customer: Mr. Ron DiFrancesco
Associate and Senior Consultant
Golder Associates, Inc.
2108 W. Laburnum Ave., Suite 200
Richmond, Virginia 23277

Project Location: Bremo Bluff, VA

Project Scope: Treatability Study for Dominion's East Ash Pond

GWTT Ref#: 6410

Dear Mr. DiFrancesco:

Ground/Water Treatment & Technology, LLC (GWTT) is pleased to submit this report which has been prepared to detail the findings of a laboratory study in accordance with our proposal dated September 8, 2015.

Please find as follows:

Summary

Approximately 20 gallons of water from the Bremo East Ash Pond were collected on November 23, 2015 and received in the laboratory on November 25, 2015. The water represents what is called pore water from the East Ash Pond.

The purpose of this testing is to determine the effectiveness of chemical precipitation in treating the water to discharge standards laid out in the Virginia Department of Environmental Quality draft permit. The treatability process was performed to determine the degree of metals reduction through GWTT's chemical precipitation pre-treatment system.

When designing a treatment process it is required that the discharge standards are known. In this case they are yet to be finalized for this particular site. The discharge criteria in the draft permit are included in Table 1 containing the sampling results from the treatability study.

The sample received had a significant quantity of very fine particles that had settled at the bottom of the containers. Each of the containers was not mixed to simulate a well point system. The solids were black in color.

Samples Collected

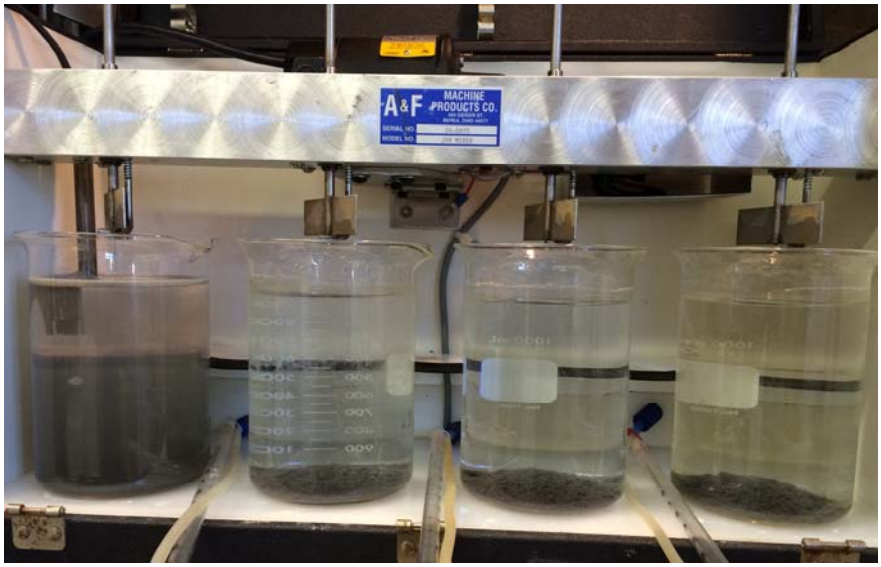
The following samples were collected and analyzed during the treatability study:

1. Untreated water (INFLUENT)
2. Chemically precipitated effluent passed through a 5-micron (um) filter (CHEM PRECIP)
3. Chemically precipitated effluent passed through a 0.5-um cartridge filter (FILTRATION)
4. Ion exchange resin treated water (TREATED)

Five gallons split from the total volume of the sample (20 gallons) were mixed completely for the treatability testing process. A split sample for analyses was prepared for the laboratory, labelled INFLUENT. The untreated water was then aerated for 15 minutes to reduce the amount of dissolved metals in the waste stream. Following the aeration step, the pH of the aerated sample was increased to approximately 9.5 standard units (s.u.) using sodium hydroxide to decrease the solubility of the metals in the waste stream. After the pH was adjusted, a coagulant and a flocculent were added to begin the chemical precipitation process. After the precipitation chemicals were added and allowed to completely mix, the samples were allowed to settle for 10 minutes to simulate clarification.

The decanted effluent water was passed through a 5-um filter and a split sample was collected and analyzed by the laboratory, labelled CHEM PRECIP. The filtered sample was filtered again through a 0.5-um filter to determine the amount of dissolved metals remaining in the sample. A split sample of the sub-micron filtered water was collected for analysis by the laboratory, labelled FILTRATION.

Water that was filtered through a 0.5-um cartridge filter was collected for the next unit operation to reduce the dissolved metals concentrations that remain from the chemical precipitation process. Ion exchange resin was placed into vessels to simulate the required empty bed contact time (EBCT) of the full scale treatment plant. Two types of resins were tested in series; the first resin was a cationic resin to reduce metals such as copper, nickel, lead and zinc, followed by an anionic resin that will reduce metals such as arsenic, selenium and thallium. The filtered sample was pumped through both resin beds, and a sample was collected and analyzed by the laboratory, labelled TREATED.



Beaker 1	**Beakers 2,3 and 4**
o Untreated o Solids Settling	o Aerated for 15 minutes o pH adjustment with hydroxide to pH of approximately 9.5 o Varying Coagulation Dosages o Varying Flocculation Dosages o Solids Settling

Treatability Results

The results of the analytical testing, along with the draft permit discharge limits for Bremo, are presented in Table 1. The untreated East Ash Pond sample had elevated levels of copper, lead and total suspended solids when compared to the limits in the draft permit, as shown by the highlighted yellow values. The nickel concentration is close the permitted discharge limit, and may be a contaminant of concern if the concentration increases slightly.

The untreated influent sample of East Ash Pond pore water from the previous treatability testing performed in July 2015 was also compared to the draft permit limits for Bremo. The untreated pore water sample from July 2015 had elevated levels of copper, lead, nickel and total suspended solids when compared to the proposed limits for Bremo in the draft permit, as shown by the highlighted yellow values presented in Table 1.

It should be noted that there was an elevated concentration of arsenic in the untreated East Ash Pond sample when compared to the concentration in the previous East Ash Pond pore water sample, but neither of these values were above the draft Bremo permit limit for arsenic.

A subsample of the East Ash Pond untreated influent was later analyzed for dissolved metals in order to determine if the metals concentrations were dissolved in the wastewater or could be attributed to the elevated total suspended solids in the sample. This step was performed to mimic the mechanical filtration that is currently on-site using bag and cartridge filters. The results are shown in Table 2. A majority of the metals of concern in the treatability testing were reduced to below permit limits through mechanical filtration. A notable exception is that the concentration of selenium in the filtered sample was higher than the draft permit limit.

The treatability study results indicate that the treatment process including aeration, hydroxide precipitation, followed by coagulation/flocculation/settling will reduce the contaminants of concern to below the Bremo discharge limits described in the draft permit.

We trust this report is fully responsive to your request. If you have any questions regarding this matter please contact me.

Best Regards,

Rob Orlando
Chief Enginer

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GWTT
Ground/Water Treatment & Technology, LLC

Beyond Water Treatment

Table 1
Laboratory Bench Test Results - Bremo East Pond

PARAMETER	TREATABILITY TESTING RESULTS										BREMO PERMIT LIMITS		
	EAST POND PZ-2 070115	EAST POND PZ-2 112315											
	INFLUENT Q	**INFLUENT** Q	MDL	**CHEM PRECIP** Q	MDL	**FILTRATION** Q	MDL	**TREATED** Q	MDL	MINIMUM	MONTHLY AVERAGE	DAILY MAXIMUM
Total Metals (mg/L)												
Antimony	**0.007**	**ND**	0.008	**ND**	0.008	**ND**	0.008	**ND**	0.008	NL	2.1	2.1
Arsenic	**0.061**	**0.121**	0.002	**0.027**	0.002	**0.027**	0.002	**ND**	0.002	NL	0.29	0.53
Cadmium	**0.00072** U	**ND**	0.001	**ND**	0.001	**ND**	0.001	**ND**	0.001	NL	0.0018	0.0032
Chromium	**0.02**	**0.02**	0.002	**ND**	0.002	**0.003** J	0.002	**0.002**	0.002	NL	0.12	0.22
Copper	**0.051**	**0.055**	0.002	**0.004** J	0.002	**0.004** J	0.002	**0.005**	0.002	NL	0.012	0.023
Lead	**0.026**	**0.026**	0.002	**0.002** J	0.002	**ND**	0.002	**ND**	0.002	NL	0.019	0.035
Mercury	**0.00014** U	**0.00009** J	0.00006	**ND**	0.00006	**ND**	0.00006	**ND**	0.00006	NL	0.0015	0.0028
Nickel	**0.046**	**0.029**	0.004	**ND**	0.004	**ND**	0.004	**ND**	0.004	NL	0.031	0.057
Selenium	**0.0037** J	**0.005** J	0.003	**0.005** J	0.003	**ND**	0.003	**ND**	0.003	NL	0.0096	0.018
Silver	--	**ND**	0.002	**ND**	0.002	**ND**	0.002	**ND**	0.002	NL	0.0027	0.005
Thallium	--	**ND**	0.004	**ND**	0.004	**ND**	0.004	**ND**	0.004	NL	0.0014	0.0014
Zinc	**0.034**	**0.036** J	0.007	**ND**	0.007	**0.023** J	0.007	**0.013** J	0.007	NL	0.11	0.21
General Chemistry (mg/L)												
Total Suspended Solids	**24600**	**790**	NA	**ND**	NA	**ND**	NA	**ND**	NA	NL	30	100
Oil and Grease, Hem-Grav	**2.8** U	**ND**		--		--		**ND**		NL	15	20
TPH, SGT-HEM	**2.8** U	**ND**		--		--		**ND**		NL	NL	NL
Hexavalent Chromium	**0.0049** U	**ND**	0.003	**ND**	0.003	**ND**	0.003	**ND**	0.003	NL	0.018	0.034
Ammonia-N	**0.08** J	--		--		--		--		NL	9.6	14
Hardness (as $CaCO_3$)	--	--		--		--		--		NL	MONITOR	MONITOR
Ph (standard units)	**8.03**	**7.927**		--		--		--		6.0	NL	9.0
Anions (mg/L)												
Chloride	**10.6**	**3.02**	0.054	**18.7**	0.054	**22.1**	0.054	**198**	0.054	NL	450	820
Sulfate	--	**45.6**	0.051	**44.8**	0.051	**46.3**	0.051	**0.352** J	0.051	NL	NL	NL
Acute Whole Effluent Toxicity (%)												
Ceriodaphnia Dubia	--	--		--		--		--		100	NL	NL
Pimephales promelas	--	--		--		--		--		100	NL	NL
Chronic Whole Effluent Toxicity (TU_c)												
Ceriodaphnia Dubia	--	--		--		--		--		NL	NL	6.25
Pimephales promelas	--	--		--		--		--		NL	NL	6.25

NOTES
ND - Non Detect
Q - Qualifier
J - Estimated Concentration
U - Undetected
NL - No Limit
Highlighted Limits indicate that the untreated concentration is greater than effluent discharge limit for the specified constituent

Table 2
Laboratory Bench Test Results - Bremo East Pond Dissolved Metals

PARAMETER	EAST POND PZ-2 112315			BREMO		
	INFLUENT	Q	MDL	MINIMUM	AVERAGE	MAXIMUM
Dissolved Metals (mg/L)						
Antimony	**0.102**		0.008	NL	2.1	2.1
Arsenic	**0.068**		0.002	NL	0.29	0.53
Cadmium	**ND**		0.001	NL	0.0018	0.0032
Chromium	**0.002**	J	0.002	NL	0.12	0.22
Copper	**0.004**	J	0.002	NL	0.012	0.023
Lead	**ND**		0.002	NL	0.019	0.035
Mercury	**--**			NL	0.0015	0.0028
Nickel	**0.004**	J	0.004	NL	0.031	0.057
Selenium	**0.011**		0.003	NL	0.0096	0.018
Silver	**ND**		0.002	NL	0.0027	0.005
Thallium	**ND**		0.004	NL	0.0014	0.0014
Zinc	**ND**		0.007	NL	0.11	0.21

NOTES
ND - Non Detect
Q - Qualifier
J - Estimated Concentration
NL - No Limit
Highlighted Limits indicate that the untreated concentration is greater than effluent discharge limit for the specified constituent

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627 Mt. Hope Road
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Date: January 6, 2016

Customer: Mr. Ron DiFrancesco
Associate and Senior Consultant
Golder Associates, Inc.
2108 W. Laburnum Ave., Suite 200
Richmond, Virginia 23277

Project Location: Bremo Bluff, VA

Project Scope: Second Round of Treatability Study for Dominion's East Pond (On-site)

GWTT Ref#: 6410

Dear Mr. DiFrancesco:

Ground/Water Treatment & Technology, LLC (GWTT) is pleased to submit this report which has been prepared to detail the findings of an on-site laboratory scale study in accordance with our proposal dated September 8, 2015.

Please find as follows:

Summary

Approximately 5 gallons of water from the Bremo East Ash Pond were collected from Piezometer PZ-2 on December 27, 2015 by Golder and tested on-site by GWTT. The water represents what is called pore water from the East Ash Pond.

The purpose of this testing is to determine the effectiveness of chemical precipitation in treating the water to discharge standards laid out in the Virginia Department of Environmental Quality draft permit. The treatability process was performed to determine the degree of metals reduction through GWTT's chemical precipitation pre-treatment system.

When designing a treatment process, it is required that the discharge standards are known. In this case, the discharge limits are determined by the Virginia Department of Environmental Quality through

the draft permit being issued to Dominion. The discharge criteria included in Table 1 contain the sampling results from the treatability study as compared to the draft permit received from Golder on January 5, 2016.

The sample collected had a significant quantity of very fine grey suspended particles that were evident throughout the treatability testing. The sample had a pH of 7.3 standard units (s.u.). This sample had a different color than the samples received in Wharton, NJ by GWTT during the first treatability study (in the laboratory), which were black due to oxidation/mixing of the samples during transit.

Samples Collected

The following samples were collected and analyzed during the treatability study:

1. Untreated water (PZ2 INF)
2. Chemically precipitated effluent passed through a 5-micron (um) filter (PZ2 EFF)
3. Aerated effluent not filtered through a 5-um filter (PZ2 Mid 1)
4. Aerated and pH adjusted effluent not filtered through a 5-um filter (PZ2 Mid 2)

Five gallons collected from PZ2 were mixed completely for the treatability testing process. A split sample for analyses was prepared for the laboratory, labelled PZ2 INF. The remaining water was collected and set up in the treatability testing mobile laboratory.

The untreated water was aerated for 15 minutes to reduce the amount of dissolved metals in the waste stream. Following the aeration step, the pH of the aerated sample was increased to approximately 9.5 s.u. using sodium hydroxide to decrease the solubility of the metals in the waste stream. After the pH was adjusted, a coagulant and a flocculent were added to begin the chemical precipitation process. After the precipitation chemicals were added and allowed to completely mix, the samples were allowed to settle for 10 minutes to simulate clarification.

The decanted effluent water was passed through a 5-um filter, and a split sample was collected and analyzed by the laboratory, labelled PZ2 EFF. Each of the four sample jars tested had similar chemical additions from the previous testing, and were retested to determine the efficiency with the different water collected during this treatability test.

Beakers 1, 2, 3 and 4

- Aerated for 15 minutes
- pH adjustment with hydroxide to pH of approximately 9.5
- Single Coagulation Dosage (0.05 mL/L Water)
- Single Flocculation Dosage (1.0 mL/L Water)
- Solids Settling

A second treatability test was performed to determine the efficiency of total metals reduction at each step of the metals pre-treatment process. The sample from PZ-2 was aerated for 15 minutes and was collected for total metals analysis by the laboratory, labelled PZ2 Mid1. The sample was not filtered prior to collection, and the pH of the sample rose to 8.6 s.u.

The next process added sodium hydroxide to the aerated water to increase the pH to a value of 9.5 s.u., and the water was allowed to equalize prior to sample collection. The unfiltered sample was collected and analyzed by the laboratory, labelled PZ2 Mid2. The final pH of the sample was 9.6 s.u.

Treatability Results

The results of the analytical testing, along with the draft permit discharge limits for Bremo, are presented in Table 1 and Table 2. The untreated East Ash Pond sample had elevated levels of arsenic, cadmium, chromium (III), copper, lead, nickel, selenium, thallium, zinc and total suspended solids

when compared to the limits contained in the draft permit. The pre-treatment process reduced the elevated constituents to below the draft permitted limits, with the exception of pH, as shown in Table 1. Therefore, an additional pH adjustment step will be implemented prior to discharge, to meet the pH effluent limit.

The untreated influent sample of East Ash Pond pore water was also tested after each pre-treatment step to determine the extent of reduction of each process.

The aerated pore water sample had elevated levels of copper, lead, nickel, selenium, thallium and total suspended solids (based upon the turbidity measurement of the effluent sample) when compared to the proposed limits in the draft permit, as shown in Table 2. The sample was not filtered prior to total metals analysis.

The aerated pore water sample that was pH adjusted had elevated levels of copper, lead, nickel, selenium, thallium and total suspended solids (based upon the turbidity measurement of the effluent sample) when compared to the proposed limits in the draft permit, as shown in Table 2. The sample was not filtered prior to total metals analysis.

The treatability study results indicate that the treatment process including aeration, hydroxide precipitation, followed by coagulation/flocculation/settling will reduce the contaminants of concern to below the Bremo discharge limits described in the draft permit. These unit operations will need to be operated in conjunction with one another in order to reduce the contaminants to below the permitted discharge limits.

We trust this report is fully responsive to your request. If you have any questions regarding this matter please contact me.

Best Regards,

Rob Orlando
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GWTT
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Beyond Water Treatment

TABLE 1: Treatability Testing Results

Analyte	Method	Date	Units	Detection Limit	Reporting Limit	Final Draft Permit MA	Final Draft Permit DM	PZ2(INF)	PZ2(EFF)
								Results	Results
pH (Minimum and Maximum)	Field	12/28/2015	S.U.	0.1	0.1	6.0	9.0	7.3	9.3
Oil and Grease	HEM	12/28/2015	mg/L	1.1	5.0	15	20	ND	ND
Antimony	200.7	12/28/2015	ug/L	3.9	5.0	2,100	2,100	11.1	9.0
Arsenic	200.7	12/28/2015	ug/L	5.0	10.0	290	530	328	25.7
Cadmium	200.7	12/28/2015	ug/L	0.50	1.0	1.8	3.2	2.4	ND
Chromium, total	200.7	12/28/2015	ug/L	2.5	5.0	No Limit	No Limit	119	ND
Chromium, trivalent	calculated	12/28/2015	ug/L	NA	NA	120	220	119	ND
Chromium, Hexavalent	SM-3500-Cr-B	12/28/2015	ug/L	0.005	0.010	18	34	ND	ND
Copper	200.8	12/28/2015	ug/L	2.5	5.0	12	23	227	0.6
Lead	200.7	12/28/2015	ug/L	2.5	5.0	19	35	103	ND
Mercury	245.1	12/28/2015	ug/L	0.070	0.20	1.5	2.8	1.2	ND
Nickel	200.7	12/28/2015	ug/L	2.5	5.0	31	57	170	6.4
Selenium	200.7	12/28/2015	ug/L	5.0	10.0	9.6	18	45.8	ND
Silver	200.8	12/28/2015	ug/L	0.050	0.10	2.7	5.0	0.31	ND
Thallium	200.8	12/28/2015	ug/L	0.50	1.0	1.4	1.4	2.6	0.56
Zinc	200.7	12/28/2015	ug/L	2.5	10.0	110	210	137	9.3
Hardness as CaCO3	SM-2340B	12/28/2015	ug/L	662	662	No Limit	No Limit	336,000	240,000
Turbidity	180.1	12/28/2015	NTU	0.50	1.0	No Limit	No Limit	over range	6.51
Total Suspended Solids	SM-2540D	12/28/2015	mg/L	13.3*	13.3*	30.0	100	1,940	ND
Ammonia - N	350.1	12/28/2015	mg/L	0.0050	0.010	9.6	14	0.15	0.20
Chloride	SM-4500-CL-E	12/28/2015	mg/L	0.50	1.0	450	820	3.4	13.3
Cyanide	SM-4500-CN-E	12/28/2015	mg/L	0.004	0.008	No Limit	No Limit	ND	ND

Notes:

ug/L = micrograms per liter mg/L = milligrams per liter SU = Standard Units "--" = No Data

ND = Not Detected at the indicated detection limit MA = Monthly Average DM = Daily Maximum

Result exceeds Final Draft Permit MA and/or DM limit

Result is qualified with "J" as an estimated concentration above the Detection Limit and below the Reporting Limit

* DL and RL are being verified by Pace

TABLE 2: Treatability Testing Midpoint Results

Analyte	Method	Date	Units	Detection Limit	Reporting Limit	Final Draft Permit MA	Final Draft Permit DM	PZ2(Mid1) Results	PZ2(Mid2) Results
pH (Minimum and Maximum)	Field	12/28/2015	S.U.	0.1	0.1	6.0	9.0	8.6	9.6
Oil and Grease	HEM	12/28/2015	mg/L	1.1	5.0	15	20	--	--
Antimony	200.7	12/28/2015	ug/L	3.9	5.0	2,100	2,100	12.6	10.5
Arsenic	200.7	12/28/2015	ug/L	5.0	10.0	290	530	200	178
Cadmium	200.7	12/28/2015	ug/L	0.50	1.0	1.8	3.2	1.2	1.0
Chromium, total	200.7	12/28/2015	ug/L	2.5	5.0	No Limit	No Limit	46.2	54.0
Chromium, trivalent	calculated	12/28/2015	ug/L	NA	NA	120	220	46.2	54.0
Chromium, Hexavalent	SM-3500-Cr-B	12/28/2015	ug/L	0.005	0.010	18	34	ND	ND
Copper	200.8	12/28/2015	ug/L	2.5	5.0	12	23	67.6	82.4
Lead	200.7	12/28/2015	ug/L	2.5	5.0	19	35	35.1	40.9
Mercury	245.1	12/28/2015	ug/L	0.070	0.20	1.5	2.8	0.45	0.40
Nickel	200.7	12/28/2015	ug/L	2.5	5.0	31	57	64.7	74.8
Selenium	200.7	12/28/2015	ug/L	5.0	10.0	9.6	18	10.8	15.3
Silver	200.8	12/28/2015	ug/L	0.050	0.10	2.7	5.0	0.076	0.14
Thallium	200.8	12/28/2015	ug/L	0.50	1.0	1.4	1.4	2.2	1.8
Zinc	200.7	12/28/2015	ug/L	2.5	10.0	110	210	56.8	67.9
Hardness as CaCO3	SM-2340B	12/28/2015	ug/L	662	662	No Limit	No Limit	319,000	309,000
Turbidity	180.1	12/28/2015	NTU	0.50	1.0	No Limit	No Limit	over range	over range
Total Suspended Solids	SM-2540D	12/28/2015	mg/L	13.3*	13.3*	30.0	100	--	--
Ammonia - N	350.1	12/28/2015	mg/L	0.0050	0.010	9.6	14	--	--
Chloride	SM-4500-CL-E	12/28/2015	mg/L	0.50	1.0	450	820	--	--
Cyanide	SM-4500-CN-E	12/28/2015	mg/L	0.004	0.008	No Limit	No Limit	--	--

Notes:

ug/L = micrograms per liter mg/L = milligrams per liter SU = Standard Units "--" = No Data

ND = Not Detected at the indicated detection limit MA = Monthly Average DM = Daily Maximum

Result exceeds Final Draft Permit MA and/or DM limit

Result is qualified with "J" as an estimated concentration above the Detection Limit and below the Reporting Limit

* DL and RL are being verified by Pace

Aeration Calculations

Design Recommendations for Aeration	Minimum Time	Design Time
	10 min	**15** min

Full Scale Volume (Frac Tank) 18,000 gallons
Working Volume (Frac Tank) 15,000 gallons

Hydraulic Residence Time (HRT)

Design Flow Rate (500 GPM) $\frac{15{,}000 \text{ gallons}}{500 \text{ gallons/minute}} = 30 \text{ min}$

Maximum Flow Rate (1,500 GPM) $\frac{15{,}000 \text{ gallons}}{1{,}500 \text{ gallons/minute}} = 10 \text{ min}$

Bench Scale Air Flow Rate (scfm) **0.0075** scfm

Dosage at Aeration Time 0.075 ft^3 0.113 ft^3

Full Scale Aeration Blower 500 scfm @ 100 " H_2O

NOTES:
1 ft^3 = 7.48 gallons
60 min/hr
GPM - gallons per minute
scfm - standard cubic feet per minute

pH Adjustment Calculations

Influent pH (Bench Scale Testing) 7.3 s.u.

Flow Rate (GPM)

Design Flow	Maximum Flow
500 GPM	**1,500** GPM

Chemical Used for pH Adjustment 25% NaOH

From Bench Scale Testing **0.155** mL NaOH / L H_2O to raise pH to 9.5 s.u.

Full Scale Flow Rate (Design Flow)

$$\frac{0.155\ \text{mL NaOH}}{\text{L } H_2O} \times \frac{3.785\ \text{L } H_2O}{\text{gal } H_2O} \times \frac{500\ \text{gallons}}{\text{min}} \times \frac{60\ \text{min}}{\text{hour}} \times \frac{\text{gal NaOH}}{3{,}785\ \text{mL NaOH}} = \frac{4.7\ \text{gal NaOH}}{\text{hour}}$$

Full Scale Mass Loading (Design Flow)

$$\frac{4.65\ \text{gal NaOH}}{\text{hour}} \times \frac{10.7\ \text{lbs NaOH}}{\text{gal NaOH}} = \frac{49.755\ \text{lbs NaOH}}{\text{hour}}$$

Full Scale Flow Rate (Maximum Flow)

$$\frac{0.155\ \text{mL NaOH}}{\text{L } H_2O} \times \frac{3.785\ \text{L } H_2O}{\text{gal } H_2O} \times \frac{1{,}500\ \text{gallons}}{\text{min}} \times \frac{60\ \text{min}}{\text{hour}} \times \frac{\text{gal NaOH}}{3{,}785\ \text{mL NaOH}} = \frac{14\ \text{gal NaOH}}{\text{hour}}$$

Full Scale Mass Loading (Maximum Flow)

$$\frac{13.95\ \text{gal NaOH}}{\text{hour}} \times \frac{10.7\ \text{lbs NaOH}}{\text{gal NaOH}} = \frac{149.27\ \text{lbs NaOH}}{\text{hour}}$$

Hydraulic Residence Time (HRT)

Design Flow Rate (500 GPM) $\frac{15{,}000\ \text{gallons}}{500\ \text{gallons/minute}} = 30\ \text{min}$

Maximum Flow Rate (1,500 GPM) $\frac{15{,}000\ \text{gallons}}{1{,}500\ \text{gallons/minute}} = 10\ \text{min}$

NOTES:
1 ft^3 = 7.48 gallons
60 min/hr
3,785 mL/gallon
GPM - gallons per minute

Coagulation Calculations

Coagulant: WC-500 (polyaluminum chloride)

Flow Rate (GPM)

Design Flow	Maximum Flow
500 GPM	**1,500** GPM

From Bench Scale Testing

$$\frac{\textbf{0.050}\ \text{mL WC-500}}{\text{L } H_2O}$$

Full Scale Flow Rate (Design Flow)

$$\frac{0.050\ \text{mL WC-500}}{\text{L } H_2O} \times \frac{3.785\ \text{L } H_2O}{\text{gal } H_2O} \times \frac{500\ \text{gallons}}{\text{min}} \times \frac{60\ \text{min}}{\text{hour}} \times \frac{\text{gal WC-500}}{3{,}785\ \text{mL WC-500}} = \frac{1.5\ \text{gal WC-500}}{\text{hour}}$$

Full Scale Mass Loading (Design Flow)

$$\frac{1.5\ \text{gal WC-500}}{\text{hour}} \times \frac{11.18\ \text{lbs WC-500}}{\text{gal WC-500}} = \frac{16.8\ \text{lbs WC-500}}{\text{hour}}$$

Full Scale Flow Rate (Maximum Flow)

$$\frac{0.050\ \text{mL WC-500}}{\text{L } H_2O} \times \frac{3.785\ \text{L } H_2O}{\text{gal } H_2O} \times \frac{1{,}500\ \text{gallons}}{\text{min}} \times \frac{60\ \text{min}}{\text{hour}} \times \frac{\text{gal WC-500}}{3{,}785\ \text{mL WC-500}} = \frac{4.5\ \text{gal WC-500}}{\text{hour}}$$

Full Scale Mass Loading (Maximum Flow)

$$\frac{4.5\ \text{gal WC-500}}{\text{hour}} \times \frac{11.18\ \text{lbs WC-500}}{\text{gal WC-500}} = \frac{50.3\ \text{lbs WC-500}}{\text{hour}}$$

NOTES:
1 ft^3 = 7.48 gallons
60 min/hr
3,785 mL/gallon
GPM - gallons per minute

Flocculation Calculations

Flocculant: AP-210 (0.2% by Mass)

Flow Rate (GPM)

Design Flow		Maximum Flow	
500	GPM	**1,500**	GPM

From Bench Scale Testing: $\frac{\textbf{1.000}\ \text{mL AP-210}}{\text{L } H_2O}$

Full Scale Flow Rate (Design Flow):

$$\frac{1.000\ \text{mL AP-210}}{\text{L } H_2O} \times \frac{3.785\ \text{L } H_2O}{\text{gal } H_2O} \times \frac{500\ \text{gallons}}{\text{min}} \times \frac{60\ \text{min}}{\text{hour}} \times \frac{\text{gal AP-210}}{3{,}785\ \text{mL AP-210}} = \frac{30\ \text{gal AP-210}}{\text{hour}}$$

Full Scale Mass Loading (Design Flow):

$$\frac{30\ \text{gal AP-210}}{\text{hour}} \times \frac{8.34\ \text{lbs AP-210}}{\text{gal AP-210}} \times \frac{2\ \text{lbs AP-210 (ACTIVE)}}{1{,}000\ \text{lb AP-210}} = \frac{0.5\ \text{lbs AP-210}}{\text{hour}}$$

Full Scale Flow Rate (Maximum Flow):

$$\frac{1.000\ \text{mL AP-210}}{\text{L } H_2O} \times \frac{3.785\ \text{L } H_2O}{\text{gal } H_2O} \times \frac{1{,}500\ \text{gallons}}{\text{min}} \times \frac{60\ \text{min}}{\text{hour}} \times \frac{\text{gal AP-210}}{3{,}785\ \text{mL AP-210}} = \frac{90\ \text{gal AP-210}}{\text{hour}}$$

Full Scale Mass Loading (Maximum Flow):

$$\frac{90\ \text{gal AP-210}}{\text{hour}} \times \frac{8.34\ \text{lbs AP-210}}{\text{gal AP-210}} \times \frac{2\ \text{lbs AP-210 (ACTIVE)}}{1{,}000\ \text{lb AP-210}} = \frac{1.5\ \text{lbs AP-210}}{\text{hour}}$$

NOTES:
1 ft^3 = 7.48 gallons
60 min/hr
3,785 mL/gallon
GPM - gallons per minute

Full-Scale Media Treatment Specifications:

Media: CGS, 50 lb/ft^3

Media Vessel: Siemens, Model PV-10000

V_D, Media Fill Volume = 330 ft^3

Q_D, Design Flow Rate = 500 gal/min

EBCT, Empty Bed Contact Time = $\frac{V_D}{Q_D/7.48}$ = 4.94 min = **5** min

Bench-Scale Media Treatment Specifications:

V_B, Media Fill Volume = 0.08722 ft^3 = 0.087 ft^3 2" column diameter, 12 inch media fill height

X_B Media Weight = 4.36111 lbs

Q_B, Design Flow Rate = $\frac{V_B}{EBCT}$ x 7.48 = 0.132 gal/min = 7.9 gal/hr

500 mL/min

Conversions:
1 ft^3 = 7.48 gallons
60 min/hr

Full-Scale Media Treatment Specifications:

Media: SBG-1, 50 lb/ft^3

Media Vessel: Siemens, Model PV-10000

V_D, Media Fill Volume = 330 ft^3

Q_D, Design Flow Rate = 500 gal/min

EBCT, Empty Bed Contact Time = $\frac{V_D}{Q_D/7.48}$ = 4.94 min = **5** min

Bench-Scale Media Treatment Specifications:

V_B, Media Fill Volume = 0.08722 ft^3 = 0.087 ft^3 2" column diameter, 12 inch media fill height

X_B Media Weight = 4.36111 lbs

Q_B, Design Flow Rate = $\frac{V_B}{EBCT}$ x 7.48 = 0.132 gal/min = 7.9 gal/hr

500 mL/min

Conversions:
1 ft^3 = 7.48 gallons
60 min/hr

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Ground/Water Treatment & Technology, LLC

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Date: February 29, 2016

Customer: Mr. Ron DiFrancesco
Associate and Senior Consultant
Golder Associates, Inc.
2108 W. Laburnum Ave., Suite 200
Richmond, Virginia 23277

Project Location: Bremo Bluff, VA

Project Scope: Treatability Study for Dominion's East Pond Spiked Sample

GWTT Ref#: 6410

Dear Mr. DiFrancesco:

Ground/Water Treatment & Technology, LLC (GWTT) is pleased to submit this report which has been prepared to detail the findings of an on-site laboratory scale study of elevated concentrations of metal.

Summary

Approximately 25 gallons of water from the Bremo East Ash Pond were collected from Piezometer PZ-2 by Golder and tested by GWTT at their treatability lab in Wharton, NJ. The water represents what is called pore water from the East Ash Pond.

The Centralized Treatment System currently installed at the Bremo site will successfully reduce all the metals (at the concentrations reported in the actual data) to below the discharge limits (VPDES Permit No. VA0004138, Dominion – Bremo Power Station). This is based upon previous treatability tests performed in both our lab and on-site, using East pond contact pore water.

However, it is understood that there is a concern for the need of a final polishing unit to address the potential for a *higher than normal level of metals* (Enhanced Metals Treatment Module) to protect the effluent discharge from a potential "metals spike" that may not be fully captured by the existing treatment system. In order to perform treatability testing for the

higher than normal level of metals, the East Pond pore water sample was "spiked" with a known concentration of total and dissolved metals to simulate this spike in metals in the Pore Water.

The purpose of this testing is to determine the effectiveness of the Enhanced Metals Treatment Module in treating the water to discharge standards laid out in the Virginia Department of Environmental Quality draft permit. The treatability process was performed to determine the degree of metals reduction through GWTT's chemical precipitation pre-treatment system followed by the use of adsorptive media (fine grain limestone in conjunction with Activated Alumina.

When designing a treatment process, it is required that the discharge standards are known. In this case, the discharge limits are determined by the Virginia Department of Environmental Quality through the draft permit being issued to Dominion. The discharge criteria included in Table 1 contain the sampling results from the treatability study as compared to the draft permit received from Golder on February 19, 2016 through February 22, 2016.

The sample collected had a significant quantity of very fine grey/black suspended particles that were evident throughout the treatability testing. The sample had a pH of 7.3 standard units (s.u.).

Samples Collected

The following samples were collected and analyzed during the treatability study:

1. Untreated spiked wastewater (SPIKED)
2. Chemically precipitated effluent passed through a 0.5-micron (um) filter (FILTER PRECIP)
3. Three liters of chemically precipitate effluent passed through a fine grain limestone and activate alumina column (LIME 3L and AA 3L)
4. Six liters of chemically precipitate effluent passed through a fine grain limestone and activate alumina column (LIME 6L and AA 6L)
5. Twenty four liters of chemically precipitate effluent passed through a fine grain limestone and activate alumina column (LIME 24L and AA 24L)
6. Twenty nine liters of chemically precipitate effluent passed through a fine grain limestone and activate alumina column (LIME 29L and AA 29L)
7. Sixty seven liters of chemically precipitate effluent passed through a fine grain limestone and activate alumina column (LIME 67L and AA 67L)

Twenty-five gallons collected from PZ2 and the spiked metals solution were mixed completely for the treatability testing process. A split sample for analyses was prepared for the laboratory, labelled SPIKED, and analyzed for total and dissolved metals. The remaining water was collected and set up in the treatability laboratory.

The untreated water was treated with a chemical reducing agent (ferrous sufate) and allowed to mix for 15 minutes to react with the soluble metals in the waste stream. The sample was aerated for 15 minutes to further reduce the amount of dissolved metals in the waste stream. Following the aeration step, the pH of the aerated sample was increased to approximately 9.0 s.u. using sodium hydroxide to decrease the solubility of the metals in the waste stream. After the pH was adjusted, a coagulant and a flocculent were added to begin the chemical precipitation process. After the precipitation chemicals were added and allowed to completely mix, the samples were allowed to settle for 10 minutes to simulate clarification.

Drum Composite Sample

- Ferrous Sulfate Dose (65 mL/L of a 0.0050% solution)
- Aerated for 15 minutes
- pH adjustment with hydroxide to pH of approximately 9.0
- Single Coagulation Dosage (0.05 mL/L Water)
- Single Flocculation Dosage (1.0 mL/L Water)
- Solids Settling

The decanted effluent water was passed through a 0.5-um filter, and a split sample was collected and analyzed by the laboratory, labelled FILTER PRECIP. Filtered effluent was then pumped through testing columns containing adsorptive media (fine grain limestone and activated alumina) at a rate of 30 mL/min. The testing columns contained 24” of adsorptive media per column with a column diameter of 1”. Samples were collected from the effluent of each column at given volumes to determine the number of bed volumes pumped through the column:

Volume pumped through Column (L)	Bed Volumes
3 Liters	10
6 Liters	20
24 Liters	78
29 Liters	95
67 Liters	218

Treatability Results

The results of the analytical testing, along with the draft permit discharge limits for Bremo, are presented in Table 1. The untreated spiked East Ash Pond sample had elevated levels of arsenic, cadmium, chromium (III), copper, lead, nickel, selenium, thallium and zinc. The pre-treatment process reduced the elevated constituents to below the draft permitted limits, with the exception of selenium and thallium, as shown in Table 1. The untreated spiked sample contained two times the historical concentration of dissolved selenium and thallium when compared to the historical data.

The effluent of the pre-treatment process which contained the elevated selenium and thallium was further treated through the use of adsorptive media. The limestone reduced the remaining cationic compounds to below effluent permitted limits. The selenium and thallium were reduced through the use of activated alumina. Activate alumina has been proven to be the best available technology by the EPA for reducing anionic compounds such as arsenic, selenium and thallium in wastewater as demonstrated in this treatability testing. Activated alumina is a proven technology to reduce these compounds detected in trace levels in wastewater effluent streams.

Sample analysis shows that thallium breakthrough occurred between a total volume of 6 liters and 24 liters passed through the activated alumina test column. The activated alumina media became saturated with dissolved metals and was unable to adsorb any other metals in the wastewater. Replacement of the media once breakthrough occurs will be determined by inline process sampling.

Certain samples were re-analyzed using lower reporting limits to determine if the non-detect values found in Table 1 were below the effluent permitted limits. Thallium had a lower discharge limit than what the analytical method's reporting limit provided, so samples were rerun using EPA Method 200.8 with lower detection limits to determine the value of the non-

detect contaminants. The results in Table 2 show that the non-detect thallium values were detected at the lower detection limit, but they still met effluent discharge limits.

The treatability study results indicate that the treatment process including aeration, hydroxide precipitation, followed by coagulation/flocculation/settling followed by the use of adsorptive media will reduce the contaminants of concern to below the Bremo discharge limits described in the draft permit. These unit operations will need to be operated in conjunction with one another in order to reduce the contaminants to below the permitted discharge limits.

We trust this report is fully responsive to your request. If you have any questions regarding this matter please contact me.

Best Regards,

Rob Orlando
Chief Enginer
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GWTT
Ground/Water Treatment & Technology, LLC

Beyond Water Treatment

Table 1
Bremo East Pond PZ-2 Spiked Sample Treatability Results

PARAMETER	EAST POND PZ-2 SPIKED SAMPLE FOR METALS REDUCTION																	BREMO PERMIT LIMITS	
	SPIKED SAMPLE				FILTER	Q	LIME 3L	Q	LIME 6L	Q	LIME 24L	Q	LIME 29L	Q	LIME 67L	Q	RL	MDL	MONTHLY	DAILY
	TOTAL	Q	DISSOLVED	Q	PRECIP														AVERAGE	MAXIMUM
Total Metals (ug/L)																				
Antimony	ND		ND		ND		ND		63		ND		11	J	45	J	50	8	2100	2100
Arsenic	323		98		20		18		20		17		21		20		5	2	290	530
Cadmium	109		4	J	ND		ND		ND		ND		ND		ND		5	1	1.8	3.2
Chromium	20		ND		ND		ND		ND		ND		ND		ND		10	2	120	220
Copper	334		3	J	ND		3	J	3	J	ND		3	J	3	J	10	2	12	23
Iron	6600		ND		ND		ND		ND		ND		ND		ND		50	20	NL	NL
Lead	326		2	J	ND		ND		ND		ND		ND		ND		10	2	19	35
Mercury	0.27		ND		ND		ND		ND		ND		ND		ND		0.20	0.06	1.5	2.8
Nickel	47		17	J	5	J	4	J	ND		5	J	4	J	4	J	25	4	31	57
Selenium	16		14		9.6	J	9	J	10		13		11		9.7	J	10	3	9.6	18
Silver	ND		ND		ND		ND		ND		ND		ND		ND		7	2	2.7	5
Thallium	74		40		39		29		34		43		39		40		20	4	1.4	1.4
Zinc	620		28	J	ND		ND		ND		ND		ND		ND		50	7	110	210
							AA 3L	Q	AA 6L	Q	AA 24L	Q	AA 29L	Q	AA 67L	Q	RL	MDL	MONTHLY	DAILY
																			AVERAGE	MAXIMUM
Total Metals (ug/L)																				
Antimony							ND		11	J	ND		ND		20	J	50	8	2100	2100
Arsenic							ND		3	J	3	J	6		8		5	2	290	530
Cadmium							ND		ND		ND		ND		ND		5	1	1.8	3.2
Chromium							4	J	2.5	J	ND		ND		ND		10	2	120	220
Copper							3	J	2	J	ND		ND		2	J	10	2	12	23
Iron							ND		ND		ND		ND		ND		50	NS	NL	NL
Lead							ND		ND		ND		ND		ND		10	2	19	35
Mercury							ND		ND		ND		ND		ND		0.20	0.06	1.5	2.8
Nickel							ND		ND		ND		ND		ND		25	4	31	57
Selenium							ND		ND		6	J	6	J	7	J	10	3	9.6	18
Silver							ND		ND		ND		ND		ND		7	2	2.7	5
Thallium							ND		ND		7	J	8	J	12	J	20	4	1.4	1.4
Zinc							ND		ND		ND		ND		ND		50	7	110	210

NOTES

ND - Non Detect
Q - Qualifier
U - Undetected
J - Estimated Concentration [Estimated Concentration is defined as less than the reporting limit (RL) but greater than the method
NS - Not Sampled
RL - Reporting Limit
NL - No Limit

Highlighted Limits indicate that the concentration is greater than effluent discharge limit for the specified constituent

SPIKED is water from PZ-2 in which Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Selenium, Thallium and Zinc were added to create a water sample that approximated historically and abnormally high concentrations of these constituents.

FILTER PRECIP is water that represents the effluent from the current treatment process. The current treatment process consists of chemical precipitation followed by mechanical filtration to 0.5 micron.

Table 2
Bremo East Pond PZ-2 Spiked Sample Treatability Testing Reruns

PARAMETER	EAST POND PZ-2 SPIKED SAMPLE FOR METALS REDUCTION																BREMO PERMIT LIMITS	
	SPIKED SAMPLE				FILTER												MONTHLY	DAILY
	TOTAL	Q	DISSOLVED	Q	PRECIP	Q	LIME 3L	Q	LIME 6L	Q	LIME 24L	Q	LIME 29L	Q	LIME 67L	Q	RL	MDL	AVERAGE	MAXIMUM
Total Metals (ug/L)																				
Antimony	6.48		2.6	J	5.44		5.17		63		5.21		11		45		3	0.1	2100	2100
Selenium	16		14		9.6	J	9	J	10		13		11		9.7	J	10	3	9.6	18
Silver	ND		ND		ND		ND		ND		ND		ND		ND		1	0.1	2.7	5
Thallium	74		40		39		29		34		43		39		40		1	0.03	1.4	1.4
							AA 3L	Q	AA 6L	Q	AA 24L	Q	AA 29L	Q	AA 67L	Q	RL	MDL	MONTHLY AVERAGE	DAILY MAXIMUM
Total Metals (ug/L)																				
Antimony							1.92	J	11	J	3.88		3.76		20		3	0.1	2100	2100
Selenium							ND		ND		6	J	6	J	7	J	10	3	9.6	18
Silver							ND		ND		ND		ND		ND		1	0.1	2.7	5
Thallium							0.32	J	0.86	J	7		8		12		1	0.03	1.4	1.4

NOTES

ND - Non Detect
Q - Qualifier
U - Undetected
J - Estimated Concentration [Estimated Concentration is defined as less than the reporting limit (RL) but greater than the method
NS - Not Sampled
RL - Reporting Limit
NL - No Limit

Highlighted Limits indicate that the concentration is greater than effluent discharge limit for the specified constituent

SPIKED is water from PZ-2 in which Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Selenium, Thallium and Zinc were added to create a water sample that approximated historically and abnormally high concentrations of these constituents.

FILTER PRECIP is water that represents the effluent from the current treatment process. The current treatment process consists of chemical precipitation followed by mechanical filtration to 0.5 micron.